Wireless Vision based Real time Object Tracking System Using Template Matching

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Abstract— **In the present work the concepts of template matching through Normalized Cross Correlation (NCC) has been used to implement a robust real time object tracking system. In this implementation a wireless surveillance pinhole camera has been used to grab the video frames from the non ideal environment. Once the object has been detected it is tracked by employing an efficient Template Matching algorithm. The templates used for the matching purposes are generated dynamically. This ensures that any change in the pose of the object does not hinder the tracking procedure. To automate the tracking process the camera is mounted on a disc coupled with stepper motor, which is synchronized with a tracking algorithm. As and when the object being tracked moves out of the viewing range of the camera, the setup is automatically adjusted to move the camera so as to keep the object of about 360 degree field of view. The system is capable of handling entry and exit of an object. The performance of the proposed Object tracking system has been demonstrated in real time environment both for indoor and outdoor by including a variety of disturbances and a means to detect a loss of track**.

Index Terms— **Normalized Cross correlation, template matching, Tracking, Wireless vision**

I. INTRODUCTION

Object tracking is one of the most important subjects in video processing. It has wide range of applications including traffic surveillance, vehicle navigation, gesture understanding, security camera systems and so forth. Tracking objects can be complex [1] due to loss of information caused by projection of the 3D world on a 2D image, noise in images, complex object motion, non rigid or articulated nature of objects [2], partial and full object occlusions, complex object shapes, scene illumination changes, and real-time processing requirements.

Tracking is made simple by imposing constraints on the motion and/or appearance of objects. In our application we have tried to minimize the number of constraints on the motion and appearance of the object. The only constraint on the motion of the object is that it should not make sudden change in the direction of motion while moving out of the viewing range of the camera. Unlike other algorithms [3] the present algorithm is capable of handling the entry and exit of an object. Also, unlike [3],[4] , no color information is required for tracking an object. There is no major constraint on the appearance of the object though an object which is a little brighter than the background gives better tracking results.

There are three key steps in implementation of our object tracking system:

- Detection of interesting moving objects,
- Tracking of such objects from frame to frame,
- Analysis of object tracks to automate the disc mechanism

A basic problem that often occurs in image processing is the determination of the position of a given pattern in an image or part of an image, the so-called region of interest. The two basic cases are

- The position of the pattern in unknown
- An estimate for the position of the pattern is not available

Usually, both cases have to be treated to solve the problem of determining the position of a given pattern in an image. In the latter case the information about the position of the pattern can be used to reduce the computational effort significantly. It is also known as feature tracking in a sequence of images [5], [6].

For both feature tracking and to know the initial estimations of the position of the given pattern, a lot of different well known algorithms have been developed [7], [8] .One basic approach that can be used in both cases mentioned above, is template matching. This means that the position of the given pattern is determined by a pixel-wise comparison of the image with a given template that contains the desired pattern. For this, the template is shifted ' u' discrete steps in the x direction and v steps in the y direction of the image and then the comparison is calculated over the template area for each position (u,v).To calculate this ,normalized cross correlation is a choice in many cases [5]. Nevertheless it is computationally expensive and therefore a fast correlation algorithm that requires fewer calculations than the basic version is of interest. In this paper we propose a complete real time object tracking system which combines template matching with normalized cross correlation.

Related works are discussed in Section II and the details about template matching are discussed in Section III. In Section IV we discuss about the proposed system. The system model implementation is discussed in Section V and the results are discussed in section VI.

II. RELATED WORKS

Tracking lays the foundation for many application areas including augmented reality, visual servoing and vision

based industrial applications. Consequently, there is a huge amount of related publications. The methods used for real time 3D tracking can be divided into four categories: Line based tracking, template based tracking, feature based tracking and hybrid approaches.

Line based tracking requires a line model of the tracked object. The pose is determined by matching a projection of the line model to the lines extracted in the image. One of the first publications in this field was [9].Recently a real time line tracking system which uses multiple-hypothesis line tracking was proposed in [10].The main disadvantage of line tracking is that it has severe problems with background clutter and image blurring so that in practice it cannot be applied to applications we are targeting.

Template-based tracking fits better into our scenarios. It uses a reference template of the object and tracks it using image differences. These works nicely for well textured objects and small inter frame displacements. One of the first publications on template-based tracking [11] was using the optical flow method. In order to improve the efficiency of the tracking and to deal with more complex objects and/or camera motions, other approaches were proposed [12],[13]. In [14] the authors compare these approaches and show that they all have an equivalent convergence rate and frequency up to a first order approximation with some being more efficient than others. A more recently suggested approach is the Efficient Second Order Minimization (ESM) algorithm [15], whose main contribution consists in finding a parameterizations and an algorithm, which allow achieving second-order convergence at the computational cost and consequently the speed of first-order methods.

Similar to template-based tracking, feature-based also requires a well-textured object. They work by extracting salient image regions from a reference image and matching them to another image. Each single point in the reference image is compared with other points belonging in a search region in the other image. The one that gives the best similarity measure score is considered as the corresponding one a common choice for feature extraction is the Harris corner detector [16]. Features can then be matched using normalized cross correlation (NCC) or some other similarity measure [17]. Two recent feature-matching approaches are SIFT [18] and Randomized Trees [19]. Both perform equally well in terms of accuracy. However, despite a recently proposed optimization of SIFT called SURF [20], SIFT has a lower runtime performance than the Randomized Trees, which exhibit a fast feature matching thanks to an offline learning step. In comparison to template-based methods, feature-based approaches can deal with bigger inter frame displacements and can even be used for wide-baseline matching if we consider the whole image as the search region. However, wide-baseline approaches are in general too slow for real-time applications. Therefore they are mostly used for initialization rather than tracking. A full tracking system using only features was proposed in [21]. They rely on registered reference images of the object and perform feature matching between reference image and current image as well as between previous image and current image to estimate the pose of the object. However,

the frame rate is not very high because of their complex cost function. Moreover image blurring poses a problem for feature extraction.

Hybrid tracking approaches combine two or more of the aforementioned approaches. Some recent related publications include [22], which combines template-based tracking and line-based tracking. In [21] the authors combine line-based tracking and feature-based tracking. Even though these algorithms perform well, the line-based tracking only improves the results for a few cases and might corrupt the result in the case of background clutter. In [23] the authors use a template-based method for tracking small patches on the object, which are then used for point based pose estimation. Since this approach uses a template-based method for tracking it cannot deal with fast object motion.

III. TEMPLATE MATCHING

Template matching is an important research area with strong roots in detection theory [24],[25]. It has obvious applications in computer and robot vision, stereography, image analysis and motion estimation [24]. Template matching in the context of an image processing is a process of locating the position of a sub image within an image of the same, or more typically, a larger size[26],[28],[27]. Template matching can also be described as a process to determine the similarity between two images. The sub image is referred to as the template image and the larger image is referred to as the search area (main image) [25], [26], [28], [27]. The template matching process involves shifting the template over the search area and computing a similarity between the template image and the window of the search area over which the template [25], [26], [29], [27]. These shifting and computing processes operate simultaneously and do the repetition until the template image lies on the edge of the search area. For the image processing purpose, the most common technique for measuring the similarity between two-dimensional images is by using cross correlation method. A correlation measure is determined between the template and respective windows of the search area to find the template position which has maximum correlation [25], [30]. Generally, for two-dimensional image, the correlation coefficient is computed for the entire area on the template image shifted on the main image.

The correlation between two signals (cross correlation) is a standard approach to feature detection as well as a component of more sophisticated techniques.

A. Template Matching by Cross Correlation.

Correlation based matching is a simple, yet very popular technique in pattern recognition with images. The basic method consists of forming a correlation measure between a template T and image I $(I \otimes T)$ and determining the location of a correspondence by finding the location of maximum correlation. Usually I is much larger than the template.

A common measure of dissimilarity is

$$d = \sum (I - T)^2 = \sum I^2 - 2\sum IT + \sum T^2 \qquad (1)$$

Where the sum is over pixels in the template T and the image I. The value of 'd' will be small when I and T are almost identical and large when they differ significantly. Since the term $\sum (IT)$ will have to be large whenever,'d' is small, large value of $\sum (IT)$ similarly indicates the location of a good match of the template. Notice that $\sum (IT)$ is the cross correlation of the two signals I and T.

The simple cross-correlation is called unnormalized and it has several major shortcomings. If a certain pixel in the image has an abnormally large value, the $\sum (IT)$ associated with this location is likely to have a large value even though no good match exists. And since zeros do not contribute to the correlation value, a good match containing zeros will possible have a small value. To overcome these problems, normalized cross-correlation (NCC) is often used instead, in which the measure is formulated as

$$\rho(u, v) = \frac{\sum_x \sum_y \left[\tilde{T}(x, y) \tilde{I}(x \pm u, y \pm v) \right]}{\sqrt{\sum_x \sum_y \tilde{T}^2(x, y)} \sqrt{\sum_x \sum_y \tilde{I}^2(x \pm u, y \pm v)}} \qquad (2)$$

In this equation (2), I is an image of image size n x n with a search window of a larger image and T is a template of image size n x n; $\tilde{T} = t - \mu_T$, and μ_T is the average intensity of T. This formula keeps ρ in the range -1 to 1, with a value close to 1 indicating a better matching.

For equation 2 to be effective, a prior accurate knowledge of the pattern T is required. For the detection of detonators, we assume the shape of a detonator is fixed and known. However, the orientation of the detonator in images can be changing and multiple templates with varying orientations have to be used.

Now let as assume that

$$T(x, y) = M(i, j) \text{ and}$$

$$I(x + u, y + v) = N(i, j) \qquad (3)$$

With image size as mentioned above for both I and T.

For a sample image (contains left and right breast images), the position, orientation and size need to be observed. These criteria are important in obtaining the best output for the matching process. Unfortunately, most images do not satisfy these criteria. Therefore, some techniques are included for preprocessing purpose to get the proper images such as flip image, region of interest (ROI) and image binarization. These techniques are not the major work for this project. Therefore, these techniques are not discussed in this paper. The correlation method is implemented using the Fast Fourier transform and modified into discrete correlation expression for computer usage. Discrete Correlation is a mathematical process of comparing one image with another image discretely. The resulting image is a two- dimensional expression of equivalence.

Supposedly, the relation between template image and search area (main image) is defined as;

$$CC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} M(i, j) N(i, j)}{\left[\sum_{i=1}^{n} \sum_{j=1}^{n} M^2(i, j) \sum_{i=1}^{n} \sum_{j=1}^{n} N^2(i, j) \right]^{\frac{1}{2}}} \qquad (4)$$

$$M(i, j) = cN(i, j)$$

$$CC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} cN(i, j) N(i, j)}{\left[\sum_{i=1}^{n} \sum_{j=1}^{n} c^2 N^2(i, j) \sum_{i=1}^{n} \sum_{j=1}^{n} N^2(i, j) \right]^{\frac{1}{2}}} \qquad (5)$$

$$CC = \frac{c \sum_{i=1}^{n} \sum_{j=1}^{n} N^2(i, j)}{\left[\sum_{i=1}^{n} \sum_{j=1}^{n} c^2 N^2(i, j) \sum_{i=1}^{n} \sum_{j=1}^{n} N^2(i, j) \right]^{\frac{1}{2}}} \qquad (6)$$

Let CC=1, then for some constant c, the correlation coefficient will result as a value 1, proving the 100% similarity between both images. This theory is applied together with the discrete correlation expression in this system. The equation for the two-dimensional discrete correlation is given by [5];

$$Out(k, l) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} In1(m, n) In2(k + m, l + n) \qquad (7)$$

Where $In1$ and $In2$ are the input images and Out is the output image. MxN is the dimension of both images and possibly they have different dimensions and sizes, however, it will filled in with certain pixel values to allow the matching process. The $In1$ and $In2$ are called the search area and the template image respectively. The output will reveal the resultant image and its position of the

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greatest match between the search area (main image) and the template.

IV. PROPOSED SYSTEM

An overview of the proposed system as a finite state machine (FSM) is given in Figure 1.The system starts with an initialization phase, and then uses the template-based tracking algorithm to track the object. If the template-based tracker is unable to recover the pose within a certain number of attempts the initialization is invoked again.

Template-based Tracking Algorithm

We use the NCC algorithm for template-based tracking. The object is tracked using this method until a loss of track is detected,

Given: Input image I ; orientation of the object initialize an output array with the same size as the input image

[1] Set an initial threshold value for thresholding the correlation result. Normally, it is set at 0.7-0.8
[2] Repeat the following steps until the result is satisfactory.
   ➢ Construct the correlation filter template T using an empirical model method.
   ➢ Perform normalized cross-correlation of I with T , and store the result in the output array.
   ➢ Threshold these correlation values. If any value is larger than the threshold, set the corresponding point in the output array to 1, otherwise to 0
   ➢ If the result is not satisfactory, adjust the threshold or the correlation filter template and continue
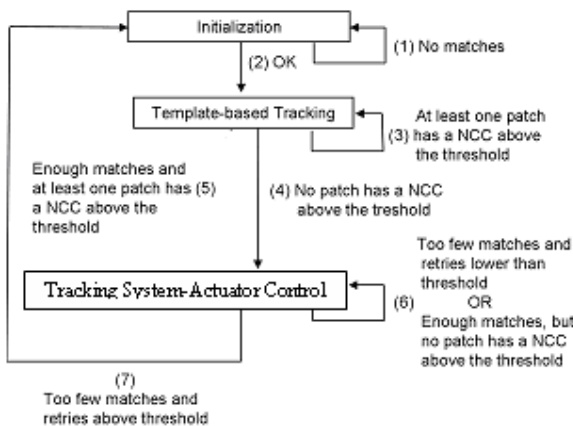[3] End repeat [1] & [2]

Figure 1.   Overview of the proposed tracking system

A. Required Information

In our system we use a textured 3D model of the object. This model can either be created manually or semi-automatically with commercially available products. One point to note is that it is advisable to use the same camera for texturing the model and for tracking, because this minimizes difficulties due to different image quality and image formation conditions.

For the initialization registered images of the object called key frames, are required. They can be created directly from the textured model by rendering it from different views. If the real-world metric pose is required, the correct intrinsic camera parameters have to be provided.

B. Initialization

When initializing, features are extracted from the current image and matched to the features extracted in the key frame. The pose can then be estimated from the 3D object points and corresponding 2D feature points in the current image. Since the tracker is using a textured model of the object the accuracy of the initial pose estimation is not very critical. If on the other hand the reference templates used for tracking were extracted from the current image, the precision of the initialization procedure would be a major issue, because the quality of the tracking result depends directly on the quality of the templates used for tracking. Hence we decided to directly use the templates taken from the textured model in our system.

C. Reference Patch Extraction

The textures of the reference patches, which are required for tracking, are taken from the textured model or each patch the object is rendered so that the patch is oriented parallel to the image plane. It is also important to ensure that the relative sizes of the object patches are reflected in the size of the rendered patches, since the number of pixels in a patch is directly proportional to its importance during tracking. Since the pose parameters used to render the patches are known, the reference patches can be directly extracted from the rendered image. These reference patches are then reduced a few times in size by a factor of two to create a stack of reference patches at different scales, which are used to speed up the tracking in a coarse-to-fine approach.

D. Visibility Test

Attempting to track patches which are not visible will lead to erroneous results. Hence it is necessary to ascertain the visibility of every patch. This test is performed by rendering the model with OpenCV and using the occlusion query extension to test which patches are visible and which are occluded. The visibility test is performed for each frame using the pose estimated in the previous frame. Thanks to the occlusion query extension the visibility test can be performed very fast, so that it does not interfere with the tracking performance

E. Loss Of Track

Determining when the tracker lost the object is important in order to switch to the proposed algorithm. In our system this is accomplished by computing the normalized cross correlation (NCC) between the reference patch I^{*}_{k} and the current patch I_{k} after the end of the optimization for all visible patches.

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Let I^* be the reference image and I the current image. Further 'p' be the pixel coordinates of the pixels in the reference image The NCC between two patches is defined as:

$$NCC\left(I_k^*, I_k\right) = \frac{\sum_{p_k}\left(I_k^*(p_k) - \mu_k^*\right)\left(I_k(p_k) - \mu_k\right)}{N^2 \sigma_k^* \sigma_k} \tag{8}$$

Where N_k is the number of pixels of each patch, μ_k^* and μ_k are the mean pixels intensities and σ_k^* and σ_k their standard deviations. If the NCC of a patch falls below a certain threshold, it is excluded from the tracking. The loss of tracking an object occurs mainly due to the presence of either due to fast movement of the object or else due to tracking object is out of focus. To avoid the loss of tracking we propose a tracking system which could be able of tracking the object in 360degree rotation. Basically in this paper the tracking of the object is considered only in the 'x'-direction .In this paper we are not going to deal with the mechanical design of the rotational disc mechanism where as we would be dealing with tracking the object continuously without any loss of the object which is under test. Complete control of the tracking system is done through wireless interface using RF 433 MHz RF module from the remote place which would be discussed in the following section in detail.

V. TEMPLATE MATCHING SYSTEM MODEL IMPLEMENTATION

This proposed system model consists of three major subdivisions
   A. Hardware setup
   B. Wireless camera Interface with OpenCV
   C. Decision Making rule for continuous tracking of object based on ROI

A. Hardware setup

This section deals with the rotational disc arrangement of the tracking system. The system utilized with single stepper motor to account for the tracking of the object in x-direction movement of the object.   As presented in Fig. 6 motor is operated using an electronic stepper motor driver circuit. We have used Wireless Transmitter and Receiver of 433MHZ for transmitting and receiving the data from the remote computer and the rotational disc arrangement on which the wireless Camera is being mounted. At the receiving section the wireless camera would be keep on tracking the object about 360 degree rotational controls is done by means of stepper motor interface along with the microcontroller ATMEL89C52.   The received data are processed based on the decision making rule which is being imposed in the microcontroller. The motor driver circuits are in turn controlled by the tracking program through the data received from the remote PC based on the information of the tracking object is under test. Rotational disc

mechanism implies the motion of the camera is governed by the motor installed horizontally.

B. Wireless Camera Interfacing

In order to track the object using Template Matching through NCC based approach we have implemented an Wireless vision interface model for acquiring the real time images from remote place through JK wireless Surveillance camera. For tracking the objects based on user defined template OpenCV is used. To grab the image we have used Zebronics image grabber TV tuner for acquiring the image from wireless camera through 2.5GHz video receiver module interfaced with PC. To interface the Image grabber and OpenCV we have used a Dynamic Link Library files vcapg2.dll. To track the object completely an efficient decision making rule is being implemented by software approach i.e., if-else and then conditions based on the movement of the object on 'x'-directions.

C. Decision Making Rule for Object Tracking

Our object tracker module generates the trajectory of an object over time by locating its position in every frame of the video. In our implementation the tasks of detecting the object and establishing correspondence between the object instances across frames are performed simultaneously (i.e multithreaded). The possible object region in every frame is obtained by means of our object detection module, and then our tracker module tracks the object across frames. In our tracking approach the object is represented using the Primitive Geometric Shape Appearance Model i.e., the object is represented as a rectangle.

The object tracking module takes the positional information of x & y co-ordinates of the system of the moving object as an input from the object template module based on the ROI. This information is then used to extract a square image template (whenever required) from the last acquired frame. The module keeps on searching it in the frames captured from that point. Whenever found it displays a red overlaid rectangle over the detected object. If the template matching doesn't yield any result (signifying that the object has changed its appearance) a new template is can be selected based on the user interest on the real time video sequence.

Further on the (x, y) co-ordinates of the tracked object are calculated and passed on to the rotational disc module from the PC through wireless interface for analysis and automation.

D. Algorithm for the Tracking Module based on Decision making rule:

   i.   Get the positional information image I(x ,y) frame size of the object it is generally considered with 320x240
   ii. Generate a image template T with size as mentioned in Section III A by extracting a square image from the last frame grabbed by the camera. The template is extracted in the form of a square whose image coordinates are given by

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-Top, Left corner: (x - u, y - v)
-Top, Right corner: (x + u, y - v)
-Bottom, Left corner: (x - u, y + v)
-Bottom, Right corner :(x+u, y+v)

iii. Search the generated template T in the last frame grabbed by the camera. This is done by using an efficient template matching algorithm based on NCC.

iv. IF the template matching is successful transmit the data through RF Transmitter 433MHz through serial Port
ELSE IF the tracker has NOT detected motion of the object then stop automation of the wireless camera module setup.
AND the detector has
THEN goto STEP 1 (get a new template)
ELSE goto STEP 5 (get the x, y position)
ELSE goto STEP 1 (get a new template)

v. Obtain the position T(x, y) of the match and pass it on to the rotational disc x-direction automation module for analysis.

vi. Goto Step iii.

The below Table I shows the complete details how the object would be tracked based on the information of the co-ordinates and exactly serial data for controlling the Rotational Disc Camera Mounting setup through Wireless RF 433MHz.

TABLE I.   Automation Of Tracking Module And Its Control Word

Object Tracking module Direction	Automation of the Tracking system Based on the Co-ordinates of the Template Matching in the Frame	Wireless Serial Data Transfer Based on Coordinates of the Object Present to the Receiver Section
LEFT	Move the camera towards direction of the object by rotating the stepper motor in Anti Clockwise Direction	'R'
RIGHT	Move the camera towards direction of the object by rotating the stepper motor in Clockwise Direction	'L'
IDEAL	Stop the movement of the actuators	'S'

VI. RESULTS

Results are presented of the experiment performed using the tracking Finite State Machine as shown in the Figure 1.The experiment was conducted for various images acquired from Wireless pinhole camera interfaces with Rotational Disc Mechanism for through low cost frame grabber Zebronic TV tuner card programmed using OpenCV.

The template matching program written in VC++ environment along with some predefined function available in OpenCV environment. To make the system
more versatile for various environmental conditions we tried to implement a concept of software approach based threshold adjustments which would be helpful for better template matching based tracking.
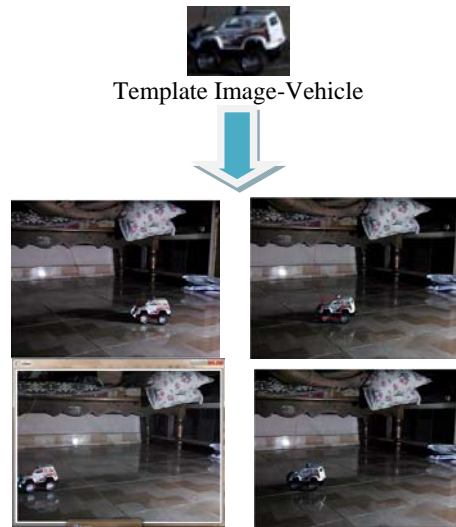

Template Image-Vehicle

Figure 2. Template Matching based Vehicle Tracking Prototype with real time images of frame size 320x240

Template Image-Face

Figure 3. Template Matching based Face Tracking
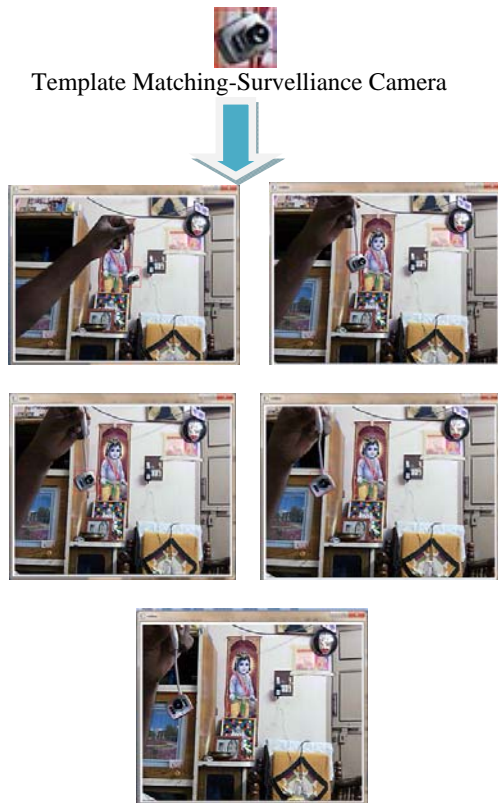
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Template Matching-Survelliance Camera

Figure 4. Template Matching based Surveillance Camera Tracking with real time images of frame size 320x240 to move the stepper motor actuator towards Left side- Clockwise Direction

Figure 5. Template Matching based Surveillance Camera Tracking with real time images of frame size 320x240 to move the stepper motor actuator towards Right side –Anticlockwise Direction

When the sequences of images is within the region then the tracking is smoother where else when the object being tracked is out of focus then the camera should be atomized through stepper motor so that the object being tracked would not be missed out which is being discussed in the above section TABLE I. In the result we have consider three objects Vehicle prototype, Human Face, Surveillance camera movement with reference template match compared with actual images tracked output frames are shown in the Figure 2,3&4,5 respectively

CONCLUSIONS

In this paper we have implemented the template matching based on NCC algorithm with real time tracking under non-ideal environment irrespective of the lighting conditions. The system has been automated using rotation disc camera mount mechanism setup which is synchronized with the algorithm. Such an automated object tracking system can be used in applications Defense application such as Automatic target tracking, Autonomous target hitting through turret by classifying the templates whether it is enemy objects or not. Future focuses on tracking multiple objects at the same time as well as on improving tracker accuracy during camera motion. Even stereo vision based tracking system can be carried out for maximum coverage of the objects and also to track multiple objects too.

ACKNOWLEDGMENT

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